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Radiographic imaging of calcaneal fractures – the surgeons view point

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Summary

This paper presents a detailed description of calcaneal fractures, which are underestimated and neglected despite their relatively high frequency. In association with significant anatomic destruction of the calcaneus they lead to unsatisfactory results of fracture treatment. Radiographic features of a healthy calcaneal bone together with pathomechanism and radiographic attributes of most common fracture types are presented. The prognostic role of the posterior talo-calcaneal joint and extraarticular anatomy of the calcaneus are emphasized. Special attention is directed to the methods of calcaneal imaging, especially the most valuable in the author's opinion – lateral radiographic view and computed tomography. Other commonly used views: axial, antero-posterior or Broden, are also described, with explanation why they are rarely recommended. The widely used standard classification system for calcaneal fractures introduced by Sanders, based on computed tomography is presented. Correct x-ray imaging is the basis for further diagnostic workup and treatment, giving also valuable prognostic information. The orthopedic surgeon, who undertakes the difficult task of treating the broken calcaneus receives thorough information about bone damage, which helps to realize the consequences of injury and of possible negligence. According to the author's experience, problems discussed in this paper are rarely fully appreciated by radiologists and orthopedic surgeons resulting in, often, catastrophic consequences.

Key words: calcaneal fracture • radiological examination • Sanders classification

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Introduction

Fractures of calcaneal bone (CB) which are the most common fractures of tarsus (60%) and constitute 2% of all skeleton injuries, lead to serious clinical problem [1]. This injury is often caused by: fall from a height, traffic accident or less frequently- slip with same-height fall. It mainly concerns young, professionally active men, therefore the economic costs of such injuries are high [2, 3].

Normal shape of the CB determines the function of the whole foot. Its fractures are characterized by complicated morphology with fragmentation of bone. Most cases (70-80%) concern injuries of posterior articular surface which forms the talo-calcaneal joint [4, 5, 6, 7, 8].

In Poland, the CB fractures are an underestimated and neglected problem and according to literature and experience of authors, the diagnostics and treatment is most often improper. The methods include unnecessary plaster cast immobilization or minimally invasive surgical procedures of fracture reposition and stabilization using Rush pins, Kirschner wires and screws, which are considered to be proper treatment only in limited cases of extra-articular non-dislocated fractures. Such treatment does not allow reconstruction of normal anatomy what is mandatory for good outcome result according to latest studies [4, 6, 9, 10, 11]. Correct imaging of fractured CB is indispensable for proper diagnostics with pre-operative surgical planning and control of results, while the textbooks on orthopedic radiology dedicated only a few lines of text to such fractures what is completely irrelevant to current medical knowledge and diagnostic needs [13, 13, 14].

Anatomy of normal CB in correlation with radiological image

Radiological CB images are characterized by arched structure of bone trabeculas which resembles cathedral vault

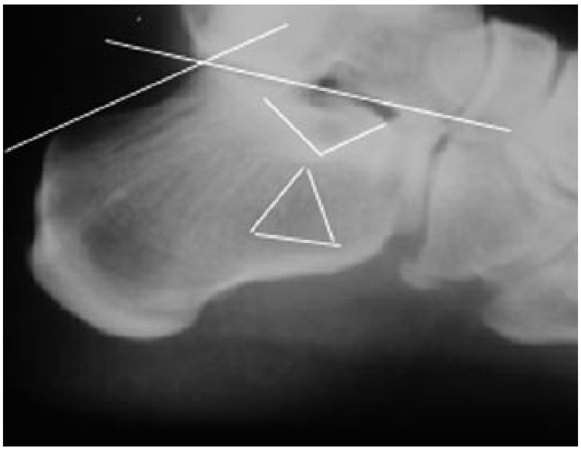

Figure 1. Radiogram of the calcaneal bone in lateral projection. Marked Bohler's and Gissane's angles and neutral triangle.

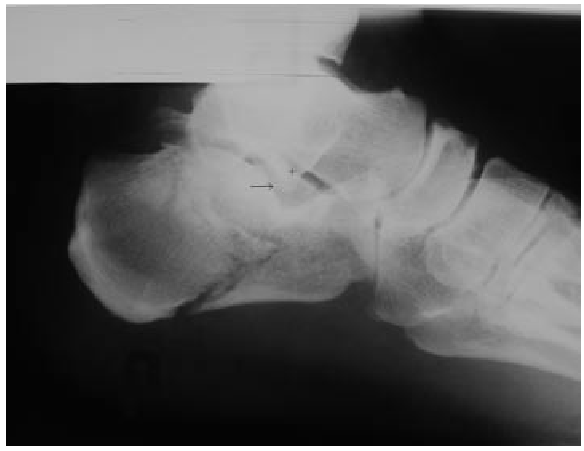

Figure 2. Comminuted fracture of the calcaneal bone with the lateral part of PAS displaced downwards and anteriorly rotated (arrow), the medial part of PAS non-displaced and marked with (+)- sign of double density.

and corresponds with axial distribution of axial loading and stress, as well as shell of cortical bone of varied thickness according to local loads- clearly seen on images in lateral projection [5, 6, 10] (fig. 1). The highest concentration of trabeculae occurs in the subtalar area, below posterior articular surface (PAS), in the so-called thalamic portion which supports the articular surface. The area below is characterized by a less concentrated arrangement of trabeculae (neutral triangle) – it is the point of decresased bone resistance, especially to axial loads (place especially vulnerable to compression fractures). Cortical bone is particularly delicate on the lateral wall of CB, which becomes bulged and comminuted during compressive fractures- widening of CB.

Along the neck of CB the cortical bone is thick and resistant forming elevations together with massive trabeculae visible on radiogram as the Gissane's angle (120-145°). Further posteriorly, the outer cortical bone edge forms the Bohler's angle (between calcaneal tuber and posterior articular surface of calcaneum). Measurement of this angle (standard 25-40°) is important for evaluation of the quality of reposition of bone fragments and possible lowering (flattening) of calcaneal bone. According to some authors it also has prognostic value [5, 6, 8, 11].

Outline of fracture patomechanism

Cancellous bone tissue ensures good elasticity of CB and protects it from injuries even to massive and sudden overloads. Vertical load through the talus (especially its cuneiform spur) exceeding its mechanical resistance at the Gissane's angle causes primary fracture line beginning at PAS and extending anteriorly [5, 15, 16].

The line which divides CB to two parts: antero-medial with sustentaculum tali (stably connected with the talus and buttressed by the tendon of flexor hallucis longus and therefore non-dislocated) and postero-lateral. Each of them contains a part of posterior articular surface. The size of PAS fragment depends on position of the foot during loading (eversion or inversion) [5, 6, 14, 15, 17]. The talus sliding medially together with the sustentaculum tali shortens and widens the calcaneum, rotates (up to 90°) and drives the lateral PAS fragment into the bone body, what leads to bulging of on the lateral wall of CB [13] (fig. 2, 3). Calcaneal tuber is displaced upwards and laterally causing flattening and widening of CB [7] (fig. 2, 3). Often the calcaneocuboid joint is also injured.

Radiological image of fractured CB

Suspicion of CB fracture requires imaging in lateral plane. It confirms the presence of fracture and is used for Bohler's and Gissane's angle measurement. It also allows evaluation of CB lowering by means of visualizing the most typical feature of comminuted CB fractures – its flattening. The PAS lowering occurs in cases when the whole articular surface is separated from the sustentaculum tali; in cases where only the lateral part of PAS is lowered (and usually rotated) the image shows sign of double density (double PAS contour) and the Bohler's angle can be normal (fig. 2). The visible rotated part of PAS (most commonly perpendicular to the rest of joint) is also described as the "sign of the rising sun". Such projection allows diagnosis of avulsive fractures

Figure 3. Horizontal cross-section of the calcaneal bone in CT scan. Visible fracture lines in the calcaneocuboid joint, calcaneal tuber impacted in varus position and rotated anteriorly, impacted lateral part of PAS bulging the thin layer of lateral cortical surface of the bone-widening of the calcaneal bone.

Figure 4. Postoperative check-up of the PAS position in Broden's view – anatomical alignement of bone fragments.

of calcaneal tuber and anterior process [5, 6]. It is advisable to comparatively examine the second, non-injured CB for analysis of correct values of the aforementioned angles.

Images in antero-posterior plane are unnecessary. Based on such image it is possible to evaluate the calcaneocuboid joint and bulged lateral surface of the CB shaft (widened calcaneum), but other views including CT are sufficient for this purpose.

Axial image (Harris views) visualizes the calcaneal tuber (varus or valgus), sustentaculm tali and to some extent also the posterior articular surface of CB. It also enables assessment of the degree of widening [2, 6, 8]. According to many authors, including us, it is unnecessary to perform imaging in this particular projection as it does not give any new information if a standard CT exam is used [2, 8, 14, 18].

Additional radiographic projections are applied for visualization of particular articular surfaces. The most common is Broden's view used for PAS evaluation [2, 6, 14] (fig. 4). These images are not necessary preoperatively (can be painful) if we use the CT, but it is useful during the surgical procedure (extremely difficult visual evaluation of the articular surface, especially after the reduction) and in postoperative follow-up (numerous artifacts in CT scan-presence of metal implant).

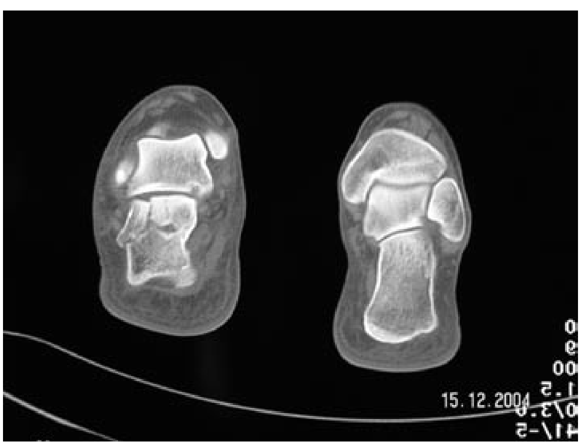

Figure 6. Comparative CT of both calcaneal bones in frontal plane. On the left- Sander's type fracture IIA, with visible lowering of the CB.

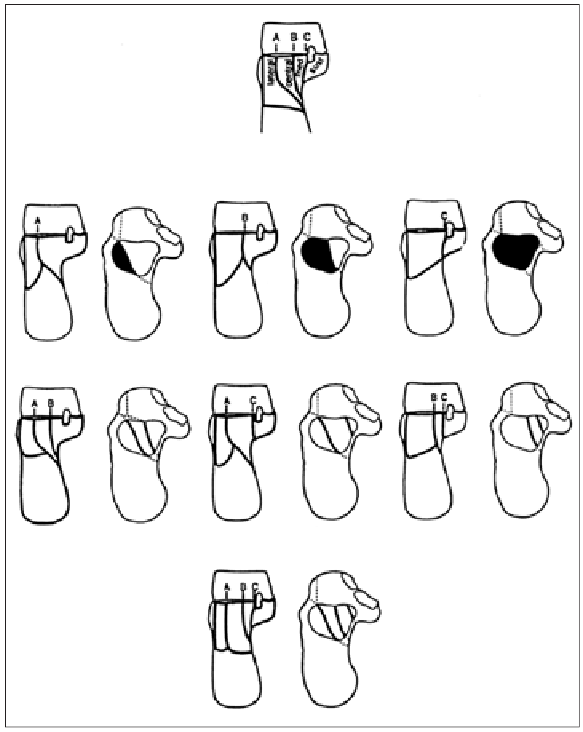

Figure 5. Sander's classification of calcaneal bone fractures based on computed tomography examination in frontal cross-section through PAS in its widest point, including the sustentaculum tali. PAS is divided by 3 lines: A-lateral, B-central, C-medial, into 3 comparable columns, which potentially are the parts of fracture: lateral, central and medial, with sustentaculum tali. Non-displaced fractures are classified as type I. Type II (second row) is a two-fragment fracture, depending on the location of fracture line: IIA – lateral fracture, IIB – cental, IIC – medial. Type III (third row) includes three-fragment fractures (IIIAB, IIIAC, IIIBC). In type IV of poor prognosis, there are 4 parts of articular surface-fourth row.

To sum up, the lateral projection is sufficient for preliminary evaluation of CB fracture, while other methods require foot manipulation, thus enforce the already strong pain; they can be impossible to perform due to often coexisting injuries (in more than 20% of cases-other lower limb fractures, in 10% – spine fractures) [1]. Moreover, neither of the described projections gives an image that would be indispensable for making the decision about the way of treatment or comparing the results (classification of fractures) [1, 14, 19]. As Cotton said in 1916, "the attempts to classify those fractures are almost as useful as attempts to classify a crushed nutshell" [5].

The introduction of CT eliminated several problems concerning a proper position of foot during the multiplanar imaging; it has become an essential tool in preoperative assessment of CB and revolutionized the understanding of its fractures. It gives better visualization of articular surfaces, estimation of the number, size and dislocation of bone fragments and the degree of damage in the adjacent soft tissues [19]. CT enabled development of precise, therapeutically and prognostically valuable methods of classification, among which the most commonly used is the one created by Sanders [14, 21, 22] (fig. 5). As a standard, the patient is laid down on the back with with knees and hips bent. Feet are usually held together, leaned against the surface of the table and both scanned for comparison (suggested particularly to radiologists and orthopedists without surgical experience). After the acquisition of lateral pilot scan, frontal views ought to be performed (every 5 mm) perpendicularly to PAS. The classification is based on the cross-section with widest visible PAS.

The plane inclined 30° to the frontal is used most frequently (due to the inclination of PAS- 50° to the long axis of CB). This cross-section does not visualize the very common anterior rotation of the PAS (around the transverse axis) as seen on lateral X-ray views (resulting from an arched shape of the posterior articular surface in both planes, frontal and sagittal). Therefore, the anterior dislocation of the PAS creates an impression of joint congruency [17]. Apart from view of the bone, such cross-section visualizes the location of peroneal and flexor hallucis longus tendons (in some cases displaced between the bone fragments what makes the reduction impossible) (fig. 6).

The next view is acquired in 90° inclination to the frontal, parallel to the long plane of CB. It provides information about the calcaneocuboid joint, antero-inferior part of PAS, sustentaculum tali and lateral wall [2, 3, 14] (fig. 3). Due to problems in understanding the definition of frontal and axial in relation to CB, in some cases we order two sections: one parallel to the sole and the other- perpendicular to it. The possibilities of digital data processing allow optional (non-standard) position of limbs, what is particularly important in cases of coexisting injuries of lower limbs [1, 3].

Conclusion

Regaining normal intra- and extra-articular anatomical condition is necessary for complete recovery. CB deformation causes degeneration of posterior talo-calcaneal joint, shortening and lowering of tarsus with its valgus or varus deformity, wedging or displacement of peroneal muscle tendons, calcaneo-fibular abutment, abnormal (horizontal) position of the talus with anterior tibio-talar abutment leading to degeneration and pain at the ankle joint, change of the lever arm for the Achilles tendon with weakening of gastrocnemius muscle [6, 7, 11].

The most important data in planning a reconstructive operation are: quantity of PAS fragments (according to Sander's classification the prognosis worsens with their higher number, therefore the surgical reconstruction of PAS is aimless in cases of excessive comminution to more than 3 parts-poor prognosis), the course of fracture lines (the more medial the PAS breakthrough the more difficult the reduction from lateral access- used most often, and suggested radiological intraoperative control in Broden's views), the direction of displacement of the bone fragment with calcaneal tuber (varus or valgus with elements of rotation), the width of CB body and degree of its lowering (determines the choice of shoes, risk of peroneal tendon and lateral malleolus entrapment on the bulged lateral calcaneal wall) and involvement of the calcaneo-cuboid joint [3, 4, 6, 9, 14, 19]. Complete therapeutically valuable diagnostics is not possible without the use of computed tomography.

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